OCCASIONAL PAPER 184 1961

MEASURING BRANCH CHARACTERS of LONGLEAF PINES

E. B. Snyder

SOUTHERN FOREST EXPERIMENT STATION
PHILIP A. BRIEGLEB, DIRECTOR
Forest Service, U. S. Department of Agriculture

The aim of the investigation reported here was to develop methods of obtaining quantitative values of branch sizes and angles for scoring plus-tree selections and inheritance studies. Measurements were made of all mature branches on 48 widely spaced longleaf pines in southern Mississippi, at the Southern Institute of Forest Genetics. The relations of branch diameter and angle effects to knot size, and of branch angle to natural pruning, were also examined.

LITERATURE

Most investigators have used a specific sampling point in the crown for branch measurement. For example, Eklund and Huss (1946) chose the largest branch nearest the point one-fourth of the way up the crown. Squillace and Bingham (1954) used average results from the ninth, tenth, and eleventh whorls from the top, corresponding to the ninth, tenth, and eleventh years of most recent growth. Many workers, including Toda (1958), Veen (1953), Miegroet (1956), and Squillace and Bingham (1954), have expressed branch diameter relative to bole diameter. Miegroet used a function of the square of the diameter of the branch and divided this by the stem diameter at mid-height. Some of these methods have been adapted in this study; others are inapplicable because of the irregular growth habit of southern pines.

METHODS

The 48 trees are in a square-mile area on the Harrison Experimental Forest. They are widely spaced, have from 16 to 29 rings at breast height, and range from 8.5 to 13.0 inches in d.b.h.

The uppermost measurement was at the fourth whorl from the top of the tree. This was the first mature whorl, i.e., where limbs branched, and corresponded to a safe climbing height. The following measurements were recorded on it and lower branches: bole diameter just above each whorl, to 0.1 inch; mean branch diameter 3 inches from the bole, to 0.1 inch; mean angle of attachment from the vertical (Busgen and Munch, 1929), to the nearest 5°; the average crown radius at the whorl, to the nearest 6 inches; and the distance from the whorl immediately above, to 1.0 inch. Branches less than 1 inch in diameter, old dead branches, and single-branched whorls were not included. Other measurements were total tree height, d.b.h., specific gravity, age, height to the living crown, and radius to 1.0 foot as sighted from the ground and derived by averaging the distances of the outer edge of crown from the trunk in the four cardinal directions. Three branches on each of 20 trees were cut as near vertical and as close to the bole as possible. Their cross-sectional outlines were measured to 0.01 square inch with a dot grid.

DETERMINING THE PLACE TO SAMPLE

Branch Sizes and Angles

Before a particular place in a tree can be specified as the sampling zone, tree architecture must be examined. An initial step was to express mean limb diameter as a ratio of stem diameter at each whorl. Data for five trees selected at random are in table 1. For the 48 trees the following zones were distinguished:

Zone 1.—Mean branch diameters for the top whorl measured were 65 percent of the stem diameters. Here branches are competing with the leader and some are almost as large as the leader. Stem diameters increased below each whorl in a stepwise pattern. The average branch angle was 55°. Typically, the relative size of the branches decreased rapidly and progressively for 5 to 10 whorls below.

Zone 2.—Still farther down, the ratio and the angles became more constant; branch dia-

meter stabilized to average 30 percent that of the bole, and angles were about 68°. This zone of stabilization included 2 to 7 whorls, depending on the tree. Limbs continued to thicken but in proportion to the thickening of the main stem. Competition apparently causes an equilibrium in growth among the branches and between them and the main stem.

Some objective way of locating this appropriate sampling zone was sought, but specifying a certain bole diameter or distance from top of tree failed to demark it. Fortunately, the zone can be recognized satisfactorily by eye. It starts at the whorl having branches of the greatest diameter and extends upward to include the first whorl from the top in which bole diameter does not change perceptibly from above the whorl to below the whorl. Four consecutive whorls in the equilibrium zone and including the whorl having the largest branches are suggested as a sample. If the zone contains fewer than four whorls, a lesser number should be used in preference to taking readings in another zone. The mean branch-to-stem ratio and the mean branch angle of these four whorls are the values to be compared to those from other trees in genetic studies.

Zone 3.—Below the largest branches of the tree, which in this group occurred one-fourth to one-third of the way up the crown, is the zone of branch senescence. Branches become smaller while the trunk becomes larger. They are doomed to die as the tree ages. The average angle of the lowest limb was 81° and in several trees the branch-to-stem ratio attained a value of 15 percent.

The means from readings within the equilibrium zone (Zone 2) reveal a frequency distribution adequate for genetic selection:

Ratio (percent)	25	26	27	28	29	30	31	32	33	35	36	37	38	39
Trees (number)	2	3	5	5	3	4	4	9	4	3	1	1	3	1

Angle (degrees)	56	57	59	62	63	64	65	66	67	68	69	70	71	74	76	78	79	81
Trees (number)	1	1	2	4	2	1	7	3	2	4	3	7	2	3	1	2	2	1

Table 1. *Branch-to-stem diameter ratios and branch angles for 5 trees chosen at random from the 48 sampled. Lines bound zones of equilibrium*

Whorl number	Tree 1		Tree 2		Tree 3		Tree 4		Tree 5	
	Ratio	Angle	Ratio	Angle	Ratio	Angle	Ratio	Angle	Ratio	Angle
	Percent	*Degrees*	*Percent*	*Degrees*	*Percent*	*Degrees*	*Percent*	*Degrees*	*Percent*	*Degrees*
1	75	50	55	70	89	50	69	60	50	55
2	54	60	50	70	53	60	67	55	52	50
3	48	65	53	70	47	60	68	60	47	55
4	37	70	39	70	46	60	56	60	41	60
5	38	60	46	70	36	60	44	55	35	65
6	33	65	26	80	28	65	52	55	30	70
7	34	70	40	75	29	70	46	55	27	70
8	30	75	21	90	25	65	41	80	22	70
9	33	70	30	75	19	90	33	60	21	75
10	21	80	27	75	17	90	36	60	22	70
11	21	90	25	80	16	90	27	70	21	80
12	19	90	25	75			32	60		
13	16	90	22	80			24	60		
14	15	90	25	80			26	65		
15	16	90					18	70		
16							25	65		
17							20	75		
18							22	75		
Means from zone of equilibrium	32	70	27	76	30	65	32	62	31	68

Also encouraging is the fact that this equilibrium-zone method appeared reasonable when tried on a few larger trees in another stand. It approximates a method subsequently used by J. Barber (personal communication) for a slash pine plantation wherein sampled whorls were in the zone beginning at a point 65 percent of total height and ending at 85 percent of total height.

Crown Radius

Measuring crown radius with a pole extended horizontally in a tree proved tedious, but the mean aerial radius of the whorl with the longest branches corresponded reasonably well with the radius as measured by sighting from the ground. For the 48 trees the mean aerial radius was 9.7 feet; the mean ground radius was 9.9 feet. The ground measurements underestimated the aerial ones 14 times, overestimated them 19 times, and were the same 15 times.

Crown radius is of no great importance *per se;* a crown can be narrow either because the branches are short or their angles are small. As photosynthetic efficiency is more closely related to branch length than to crown radius, the radius should be converted by the formula:

Branch length = crown radius x cosecant angle

BRANCH SIZE AND ANGLE EFFECTS

Deviations from a 90° attachment will produce elliptical scars whose areas are functions of the cosecant angle. Table 2 shows theoretical knot-size values for various angles. To obtain experimental indications, the regression adjustments of branch diameter on knot size were first made. The basic formula calculated was: $y = -0.865 + 0.971x$, where y is the area of the knot and x is the square of the branch diameter, both in square inches. Knot sizes, calculated on the basis of mean branch diameter, follow theoretical values satisfactorily (table 2). Observed values also appear in figure 1.

Branch angles are supposed to influence natural pruning: the more horizontal the branch, the more leverage its own weight adds toward breaking it. This natural pruning force is a function of the sine of the attachment angle, theoretical values of which are shown in table 2. The data failed to demonstrate this relation, but the mathematical procedure may be of interest. It consisted of finding how much

Table 2. *Relations between branch angles, knot size, and natural pruning force*

Branch angle	Relative knot size		Relative natural pruning force—theoretical
	Theoretical	Actual	
	Cosecant x 100	*Percent*	*Sine x 100*
90	100	...	100
85	100	...	100
80	102	...	98
75	104	105	97
70	106	106	94
65	110	...	91
60	115	109	87
55	122	108	82
50	130	112	77
45	141	130	71
40	156	140	64

of the variation in height to first live limb could be explained by possible factors. With the 704 Regression Program (Grosenbaugh, 1958), an index of determination (R^2) of 0.58 was obtained from the combination of age, height, d.b.h., an arbitrary index of tree competition, specific gravity, branch diameter, branch length, and branch angle. The most important factors were d.b.h., tree height, age, and competition, which together resulted in an $R^2 = 0.49$. The difference between 0.49 and 0.58 was divided among the small effects of the other factors, including sine angle. Further studies should be made to refine measurements, to consider other variables including the cube of the branch diameter (Miller, 1959), and to expand the range and amount of material.

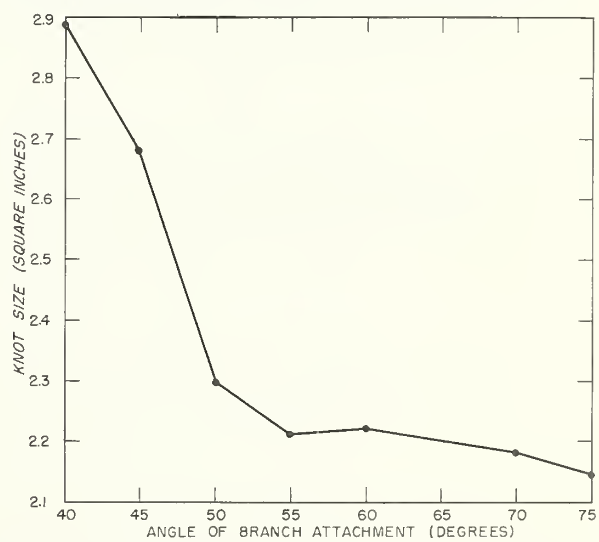

Figure 1. *Observed mean knot sizes (adjusted to the mean branch diameter) for 60 branches with various angles of attachment.*

SUMMARY

To find an appropriate place to sample branch diameters, lengths, and angles for genetic purposes, all the mature branches on 48 wide-spaced longleaf pines, varying from 8.5 to 13.0 inches in d.b.h., were measured.

Three types of branch growth were noted. At the top, branches are almost as thick as the leader and competing with it; their attachment angles are acute. Next comes a series of 2 to 7 whorls where there is an equilibrium in growth among the branches and between them and the main stem. Branches tend to thicken progressively toward the ground but in proportion to the thickening of the main stem; angles are less sharp. This zone of growth equilibrium is an appropriate place to sample for branch characters. Below it is a senescence zone where branches are smaller and are not growing in proportion to the main stem; here branch angles approach 90°.

On-the-ground readings for crown radius compared favorably to those taken in the tree. It is suggested that on-the-ground data be used but that the radii be transformed to branch lengths by multiplying them by the cosecant of the average branch angle. The effect of the sine of the angle on height to first live branch was not demonstrated even though regression adjustments were made for height, age, d.b.h., competition, specific gravity, branch diameter, and branch length. Observed values for knot size measured from 60 severed branches were, for a constant branch size, proportional to the cosecants of the angles.

LITERATURE CITED

Busgen, M., and Munch, E.
1929. THE STRUCTURE AND LIFE OF FOREST TREES. 436 pp. London.

Eklund, B., and Huss, E.
1946. [INVESTIGATIONS OF OLD FOREST CULTIVATIONS IN NORTHERN SWEDEN]. Statens SkogsforsknInst. [Sweden], Meddel. 35-(6):1-104.

Grosenbaugh, L. R.
1958. THE ELUSIVE FORMULA OF BEST FIT: A COMPREHENSIVE NEW MACHINE PROGRAM. U. S. Forest Serv. South. Forest Expt. Sta. Occas. Paper 158, 9 pp.

Miegroet, M. van.
1958. DIE BESTIMMUNG DER AESTIGKEIT IN DICKUNGEN. [EVALUATION OF BRANCHINESS IN THICKET-STAGE STANDS]. Twelfth Cong. Int. Union Forest Res. Organ. Papers 2(23): 56-62.

Miller, V. J.
1959. CROTCH INFLUENCE ON STRENGTH AND BREAKING POINT OF APPLE TREE BRANCHES. Amer. Soc. Hort. Sci. Proc. 73: 27-32.

Squillace, A. E., and Bingham, R. T.
1954. BREEDING FOR IMPROVED GROWTH RATE AND TIMBER QUALITY IN WESTERN WHITE PINE. Jour. Forestry 52: 656-665.

Toda, R.
1958. VARIATION AND HERITABILITY OF SOME QUANTITATIVE CHARACTERS IN *Cryptomeria*. Silvae Genetica 7: 87-93.

Veen, B.
1954. REPORT ON THE TEST AREAS OF THE INTERNATIONAL PROVENANCE TESTS WITH LARCH, PINE AND SPRUCE OF 1938-39 AND 1944-45, AND SUGGESTIONS FOR FUTURE TREATMENT AND ASSESSMENTS. Eleventh Cong. Int. Forest Res. Organ. 1953: 536-551.